Japanese Patent Laid-Open Number Hei 5-35207

Laid-Open Date: 1993-02-12

Application No.: Hei 03-216566

Filing Date: 1991-08-02

Int. Class. No.: G09G 3/30; G09F 9/30, 13/22

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Specification

Title of Invention: EL DRIVING DEVICE

Abstract

[Objective]

An EL driving device is disclosed with an EL light emitting element having the luminance modulation which is proportioned linearly to a gradation data voltage.

[Aspect]

Light emitted from an EL light emitting element is incident on a photodiode which is connected in a line to a condenser for storage so that a photoelectric current is generated, whereby the condenser for storage is discharged, light emitting time is controlled by reducing a gate voltage of a switching element for controlling light emission of the EL light emitting element, and the luminance modulation which is proportioned linearly to a gradation voltage applied as the gate voltage is performed.

[Claims]

[Claim 1] An EL driving device comprising:

a first switching element for charging a condenser for storage in response to a light emitting signal; and

a second switching element for controlling light emission of an EL light emitting element by switching operation in response to a gate voltage from the condenser for storage;

wherein a photodiode is connected in a line to the condenser for storage, the photodiode is arranged so as to be received light emitted from the EL light emitting element, the condenser for storage is discharged by a photoelectric current by light emitted from the EL light emitting element, and light emitting time of the EL light emitting element is controlled by reducing a gate voltage of the second switching element.

[Claim 2] The EL driving element according to claim 1, wherein a first switching element, a second switching element, an EL light emitting element, and a photodiode are formed respectively over one substrate to be a laminated structure by a thin film process.

[Claim 3] The EL driving element according to claim 2, wherein a semiconductor active layer of first and second switching elements, and a photoelectric conversion layer of a photodiode are formed by amorphous silicon layers.

[Claim 4] The EL driving element according to claim 2, wherein light emitted from an edge face which is crossing at right angles with a laminated face of

an EL light emitting element is made to be incident directly on a photodiode through an insulating layer.

[Detailed Description of the Invention]

[Industrial Field of Application]

The present invention relates to an EL driving device which is structured by combining an EL (electroluminescence) light emitting element and switching elements, and which is used for an active matrix type EL display device and an exposing system of an electronic copying and printing device, and more particularly such an EL driving device with a structure which controls easily the luminance modulation of the EL light emitting element.

[Related Art]

Fig. 6 shows an equivalent circuit for one bit of an EL driving device which is used conventionally as an active matrix type EL display device or an EL light emitting element array. This EL driving device comprises a first switching element Qw (TFT); a condenser Cs for storage of which one terminal is connected to a source terminal side of the switching element Qw; a second switching element Qd (TFT) of which a gate terminal is connected to a source terminal of the first switching element Qw and of which a source terminal is connected to another terminal of the condenser Cs for storage; and

an EL light emitting element CEL of which one terminal is connected to a drain terminal of the second switching element Qd and another terminal is connected to an EL driving power source Va.

The first switching element Qw turns ON in response to a scanning voltage Vsc pulse which is from a switching signal line Y and which is applied to the gate terminal, and data are written to the condenser Cs for storage in response to a data voltage VDA from an information signal line X by ON and OFF of this first switching element Qw. Then, the second switching element Qd turns ON by which the data voltage VDA is written to the condenser Cs for storage and the voltage is applied to the gate terminal at that time, consequently the EL light emitting element CEL is emitted by the EL driving power source Va. Also, when the data voltage VDA reaches (L), electric charges stored in the condenser Cs for storage are discharged by an OFF current of the first switching element Qw.

The EL light emitting element CEL is formed by thin film process by which a first electrode, an insulating layer, a light emitting layer, an insulating layer and a second electrode are stacked in order. The luminance L of this EL light emitting element CEL, for example in case of using ZnS:Mn as a light emitting layer, as shown in Fig. 7, becomes non-light emitting luminance LOFF or less when a driving voltage Va an alternating current is an light emitting threshold voltage VTEL or less, and the desired display luminance LON is obtained at a voltage at light emitting VPK which is high as much as the modulation voltage VMOD. And, the luminance characteristic relative to

the driving frequency is increased by the extent of 700Hz in proportion to the number of times of light emitting linearly, as shown in Fig. 8. The EL light emitting element CEL is emitted when the polarity of an applied alternating current power source is reversed, consequently the number of times of light emitting can be controlled by adjusting the conductive (ON) time of the switching element Qd.

In Fig. 6, the data voltage VDA is stored by being charged in the condenser Cs for storage by ON operation of the first switching element Qw for writing. This voltage serves as a gate voltage VG of the second switching element Qd for EL driving, and controls ON/OFF of the switching element Qd. According to this gate voltage VG, the luminance of the EL light emitting element CEL has the characteristic as shown in Fig. 9 in the voltage at the light emitting VPK. Namely, a gate voltage VG0(t) which is applied to a gate terminal of the second switching element Qd, as shown in Fig. 10(a), is expressed by a curve attenuating from the gate voltage VG0 just after writing to the condenser Cs for storage by a gradation data voltage VDA owing to discharge by an OFF current of the first switching element Qw. And, it takes t1-time to be a threshold gate voltage (non-light emitting maximum gate voltage) Vgh2 at which the switching element Qd turns non-conductive (OFF), and the switching element Qd turns the conductive (ON) condition within this period so that a driving voltage Va (Vpk $\sin\omega t$) (Fig. 11(b)) is applied to the EL light emitting element CEL. Therefore, if the gradation data voltage VDA for writing to the condenser Cs for storage is

varied, the EL driving time t1 is varied and the number of times of light emitting within t1-period of the EL driving time, consequently the gradation display of the EL light emitting element CEL can be obtained.

[Problems that the Invention is to Solve]

According to the above EL driving device, the problem is arisen that, for example, a discharge current is not stable since the gradation data voltage VDA on each line is different in one bit of an EL image bar forming one line, and the gradation data voltage VDA is often higher than a storage voltage of a condenser Cs for storage, in that case, it is charged in reverse so that the period t1 until the gate voltage VG(t) turns into OFF cannot be controlled.

Accordingly, the present inventor, as shown in Fig. 11, proposes a constitution by which a stable ON period in the second switching element Qd which controls light emission of an EL light emitting element CEL is obtained by arranging a discharge resistance R connected in a line to a condenser Cs for storage on the side of a second switching element Qd, and discharging electric charges stored in the condenser Cs for storage through the discharge resistance R.

However, according to this constitution, the problem is arisen that the gate voltage VG(t) which controls ON/OFF of the second switching element Qd, as shown by a dot line in Fig. 10(a), attenuates by time constant CsR of a capacity of condenser Cs for storage and the discharge resistance R, so that the curve falls sharply, and the EL driving time t1 does not correspond

linearly to the number of times of light emitting of the EL light emitting element CEL, consequently the number of times of light emitting of the EL light emitting element CEL which is in proportion to the gradation data voltage VDA is not obtained.

In view of the foregoing, it is an object of the present invention to provide an EL driving device by which the luminance modulation of an EL light emitting element which is in proportion linearly to a gradation data voltage is obtained.

[Means for Solving the Problems]

In order to solve the above conventional problems, the EL driving device according to claim 1 is constructed as follows. A first switching element for charging a condenser for storage in response to a light emitting signal; and a second switching element for controlling light emitting of an EL light emitting element by switching operation in response to a gate voltage from the condenser for storage. A photodiode is connected in a line to the condenser for storage, and the photodiode is arranged so as to be received light emitted from the EL light emitting element. And the condenser for storage is discharged by a photoelectric current by light emitted from the EL light emitting element, and light emitting time of the EL light emitting element is controlled by reducing a gate voltage of the second switching element.

The invention according to claim 2, in the EL driving device according

to claim 1, a first switching element, a second switching element, an EL light emitting element, and a photodiode are formed respectively over one substrate by a thin film process with laminated structure.

The invention according to claim 3, in the EL driving device according to claim 2, semiconductor active layers of a first and a second switching elements, and a photoelectric conversion layer of a photodiode are formed by amorphous silicon layers.

The invention according to claim 4, in the EL driving device according to claim 2, a beam of light emitting from an edge face which is crossing at right angles with a laminated face of an EL light emitting element is made to be incident directly on a photodiode through an insulating layer.

[Action]

According to the invention of claim 1, light emitted from an EL light emitting element is incident on a photodiode which is connected in a line to a condenser for storage so that a photoelectric current is generated, whereby the condenser for storage is discharged, light emitting time of the EL light emitting element is controlled by reducing a gate voltage of a second switching element, and the luminance modulation which is proportioned linearly to a gradation voltage applied as a gate voltage is performed.

According to the invention of claim 2, in the EL driving device according to claim 1, a first switching element, a second switching element, an EL light emitting element, and a photodiode are formed to have a thin film

laminated structure, which are formed respectively on one substrate by a thin film process, consequently the area can be enlarged.

According to the invention of claim 3, in the EL driving device according to claim 2, amorphous silicon is used for semiconductor active layers of first and second switching elements, and a photoelectric conversion layer of a photodiode, consequently a large device which has an excellent characteristic and which is manufactured easily can be obtained.

According to the invention of claim 4, in the EL driving device according to claim 2, light emitted from an edge face which is crossing at right angles with a laminated face of an EL light emitting element is made to be incident directly on a photodiode through an insulating layer, consequently a photoelectric current is generated in the photodiode and a condenser for storage can be discharged.

[Embodiment]

One embodiment of the present invention is explained with reference to Fig.1. Fig. 1 shows a simple equivalent circuit diagram of an EL driving device relating to an embodiment of the present invention, and shows for one bit of a matrix type EL display device and an EL light emitting element array. A first switching element Qw is constituted so as to provide a data voltage pulse to an information signal line X of the drain side, and a condenser Cs for storage of which one terminal is earthed is connected to the source side. And, the cathode side of a photodiode PD of which anode side is earthed is

connected to the source side of the first switching element Qw. A scanning voltage pulse is applied to a switching signal line Y which is connected to a gate of the first switching element Qw. Moreover, the source side of the first switching element Qw is connected to a gate of a second switching element Qd. Therefore, between the gate terminal of the second switching element Qd and a ground, the condenser Cs for storage and the photodiode PD are connected in a line each other. An EL light emitting element CEL and an EL driving power source Va (Va=Vpksinωt) are connected in series to the drain side of the second switching element Qd, and the source side of the second switching element Qd is earthed, consequently the EL driving power source Va of an alternating current is applied to the EL light emitting element CEL through the second switching element Qd.

Next, an operation of the above driving circuit for one bit is explained with reference to Fig.2(a) to 2(f) showing a timing chart of one frame period tFR of the minimum unit of light emitting operation. The frame period tFR is a period from rising of a scanning voltage pulse which is applied to the switching signal line Y to rising of the next one. When the scanning voltage pulse (scanning voltage Vsc) is applied to the switching signal line Y which is connected to a gate of the first switching element Qw, the first switching element Qw turns into the conductive (ON) condition. Slightly before that, the data voltage pulse (data voltage VDA) is applied to the information signal line X, consequently the condenser Cs for storage is charged (ta period) through an ON resistance (Ron) of the first switching element Qw in a time

corresponding to a pulse width of the scanning voltage Vsc. At this time, the voltage of both terminals of the condenser Cs for storage which serves as a gate voltage VG varies according to VDA(1-exp(-t/τ)(τ =Ron•Cs). And, the pulse width of the data voltage VDA is set wider than that of the scanning voltage Vsc. When the voltage which is applied to the switching signal line Y is reduced to 0, the first switching element Qw turns into the cut off (OFF) condition, and the voltage of the condenser Cs for storage which is charged up to the data voltage VDA falls to a voltage Vg by feed through owing to a capacity between a gate and a source of the first switching element Qw. When the gate voltage VG is non-light emitting maximum gate voltage Vgh2 or more, the second switching element Qd turns into the conductive (ON) condition, and after the scanning voltage Vsc falls, the EL driving power source Va is applied to the EL light emitting element CEL, consequently the EL light emitting element CEL is emitted. In the simple equivalent circuit of Fig. 1, a control circuit for synchronizing application of the EL driving power source Va to the EL light emitting element CEL with falling of the scanning voltage Vsc is omitted.

When the EL light emitting element CEL emits light, its emitted light is incident on the photodiode PD, consequently a light current (photoelectric current) Ip is generated and electric charges which are stored in the condenser Cs for storage are discharged. Then, the gate voltage VG is reduced by this discharge, a light emitting period tb shows the time to attenuate from the voltage Vg just after light emitting to the voltage Vgh2 at which the EL light

emitting element CEL turns into the non-light emitting condition, and EL light emitting intensity (Fig. 2(d)) is decided by the number of times of polar reverse of the driving power source Va between the period. Namely, the luminance of the EL light emitting element CEL in one frame period tFR is decided by the number of times of light emitting in the light emitting period tb.

In this operation, the electric charges which are stored in the condenser Cs for storage, are discharged through the photodiode PD and attenuate about lineally independently of time constant like a driving circuit of Fig. 11, consequently the EL light emitting intensity in proportion to the light emitting period tb can be obtained. Moreover, the electric charges which are stored in the condenser Cs for storage depend on the value of the data voltage VDA, so that the luminance gradation can be performed by varying the EL light emitting intensity by the data voltage VDA. Namely, when the gate voltage Vg at the maximum data voltage is Vgon, the light current Ip is set so that the period of falling from this Vgon to Vgh2 which the EL light emitting element CEL turns the non-light emitting condition is the maximum display luminance. Therefore, the light current is expressed by Ip=(Vgon – Vgh2) x Cs/tFR. And, when the data voltage VDA corresponding to voltage from Vgon to a light emitting saturated gate voltage Vgh1 is applied, the period of falling from the gate voltage Vg corresponding to this data voltage VDA to Vgh2 is the EL driving period tb, and the gradation display can be performed by modulating the display luminance. In addition, it is to be desired that (Vgh1

– Vgh2) is set as small as possible, and (Vgh – Vgh1) is set large enough compared with (Vgh1 – Vgh2). In Fig. 2(e) and Fig. 2(f), the luminance modulation is performed, by which the light emitting period tb that is necessary for the gate voltage VG to fall to the non-light emitting maximum voltage Vgh2 is controlled by varying the data voltage VDA, and the EL light emitting intensity is varied. Fig. 2(e) shows the case that all the periods of the driving power source Va correspond to the light emitting period tb, and Fig. 2(f) shows the case that three periods of the driving power source Va correspond to the light emitting period tb.

Next, if the current when the EL light emitting element CEL is not emitted is a dark current Id, it is considered that the current by the external light is added to the dark current of the photodiode PD itself. When this external light is constant under the working condition, and if it is necessary that the dark current Id is kept low in the data voltage VDA as the absolute quantity, it is preferable that variation of the gate voltage Vg by the dark current Id is kept within one gradation level. Therefore, when the gradation level is NGR, an allowable dark current Id is expressed by the following expression Id = Ip/NGR.

Fig. 3 shows a driving circuit in case that the present invention is applied to a matrix type EL display device with the number of bits of m x n. Namely, a plurality of driving circuits of one pixel shown in Fig. 1 are arranged in the upper and the lower sides, and from right to left, a gate of each driving circuit which is arranged in the direction from right to left is

connected to a switching signal line Y, and an information signal line X of each driving circuit which is arranged in the direction from the upper to the lower sides is common. The same marks are used to identify the components corresponding to Fig.1 and the detailed explanation is omitted. The EL driving power source Va is provided to the one side of the EL light emitting element CEL through an alternating current power source driving line Z.

Next, a concrete structure of an EL driving device is explained with reference to Fig. 4 and Fig. 5. Fig. 4 is a plain explanatory view of one bit of an EL driving device, and Fig. 5 is a cross-sectional view of Fig. 4 taken along A-A line. In the figures, the same marks are used to identify the components corresponding to Fig. 1. In Fig. 5, a first switching element Qw and a condenser Cs for storage are not illustrated. An EL light emitting element CEL is constituted by stacking a transparent electrode 11 of indium oxide-tin (ITO), a first dielectric layer 12 of silicon nitride (SiNx), a light emitting layer 13 of ZnS:Mn and the like, a second dielectric layer 14 of silicon nitride (SiNx), and a back electrode 15 of metal such as chrome (Cr) are laminated in order over a transparent substrate 10 of glass and the like. Switching elements Qw and Qd are constituted by stacking a gate electrode 21 of metal like as chrome (Cr), an insulating layer 22 of silicon nitride (SiNx), a semiconductor layer 23 of amorphous silicon (a-Si), an upper insulating layer 24 of silicon nitride (SiNx), and a drain electrode 25 and a source electrode 26 of metal like as chrome (Cr) which are separated and opposed to each other in order over the transparent electrode 10. And, the transparent electrode 11 is

connected to an alternating current power source driving line Z, and the back electrode 15 is connected to the drain electrode 25.

Further, a photodiode PD is formed by stacking a cathode electrode 31 of metal like as chrome (Cr), a semiconductor layer 32 of amorphous silicon (a-Si), and an anode electrode 33 of indium oxide-tin (ITO) and the like in order over the transparent substrate 10 between the EL light emitting element CEL and the switching element Qd. The second dielectric layer 14 is also used as a protective layer of the photodiode PD. The anode electrode 33 of the photodiode PD is connected to the source electrode 26 of the switching element Qd, and the cathode electrode 31 is connected to the gate electrode 21 of the switching element Qd. The external light from the side of the transparent substrate 10 to the photodiode PD is shielded with the cathode electrode 31. Also, the back side of the transparent substrate 10 is sealed with a shielding material, so that incidence of the external light on the photodiode PD and the switching elements Qw, Qd is prevented. The condenser Cs for storage is constituted by interposing a dielectric layer between two electrodes in which the upper electrode is connected to the source electrode 26 of the switching element Qd and a ground line, and the lower electrode is connected to a drain electrode of the switching element Qw and the gate electrode 21 of the switching element Qd. And, the whole of EL driving device is covered with a protective film 40 of polyimide and the like.

Next, manufacturing processes of an EL light emitting element CEL, a switching element Qd (TFT), a photodiode PD of an EL driving device which

are shown in a cross sectional view of Fig. 5 are explained simply. A transparent electrode 11 of an EL light emitting element CEL is formed by depositing indium oxide-tin (ITO) over a transparent substrate 10, and by patterning with a photo-lithographing process and an etching process. Next, a gate electrode 21 of the switching element Qd and a cathode electrode 31 of the photodiode PD are formed by depositing chrome (Cr) and by patterning with a photo-lithographing process and an etching process. Successively a first dielectric layer 12 of the EL light emitting element CEL and an insulating layer 22 of the switching element Qd are formed by depositing SiNx.

In a TFT portion, a semiconductor layer 23 and an upper insulating layer 24 of the switching element Qd are formed by depositing amorphous silicon (a-Si) and silicon nitride (SiNx) in order and by patterning respectively. In a photodiode PD portion, a semiconductor layer 32 and an anode electrode 33 of the photodiode PD are formed by depositing amorphous silicon (a-Si) and indium oxide-tin (ITO) in order and by patterning respectively.

A light emitting layer 13 of ZnS:Mn layer is formed above the transparent electrode 11, and a second dielectric layer 14 is formed by depositing SiNx so as to cover the light emitting layer 13 and the anode electrode 33. A back electrode 15 of the EL light emitting element CEL, and a drain electrode 25 and a source electrode 26 of switching element Qd are formed by depositing chrome (Cr) and by patterning with a photo-lithographing process and an etching process. A protective film 40 is formed by depositing polyimide on the whole of back side. In the above

manufacturing process, both of semiconductor active layer 23 of the switching element Qd and semiconductor layer 32 of the photodiode PD are formed with amorphous silicon, however, respective film thicknesses are different, 0.05μm and 1μm, so that they are not deposited simultaneously.

According to the constitution of the above EL driving device, light from the light emitting layer 13 of the EL light emitting element CEL is irradiated onto the side of the transparent substrate 10, and the light emitted from the edge side which is crossing at right angle with the laminated surface of the EL light emitting element is incident on the edge portion of the photodiode PD through the second dielectric layer 14. A photoelectric current is generated in the semiconductor layer 22 by this light so that electric charges which are stored in the condenser Cs for storage are made to be discharged. Also, since the electric charges are discharged through the photodiode PD, OFF resistance of the first switching element Qw is made to be large, for example, amorphous silicon (a-Si) is used as its semiconductor active layer 23, and the switching elements Qw and Qd are formed in the same thin film laminating process. Furthermore, since the semiconductor layer 32 of the photodiode PD is formed with amorphous silicon (a-Si) which is used for semiconductor active layers of the switching elements Qw and Qd, the manufacturing process can be simplified.

[Effects of the invention]

According to the present invention, light emitted from the EL light

emitting element is incident on the photodiode which is connected in a line to the condenser for storage, consequently a photoelectric current is generated and the condenser for storage is discharged, so that a gate voltage of the second switching element is reduced, the gate voltage attenuates nearly linearly, and the number of light emitting in proportion to a gradation data voltage can be controlled, consequently the uniform gradation display can be performed easily.

[Brief Description of the Drawings]

Fig. 1 is a simple circuit diagram of an EL driving device according to one embodiment of the present invention.

Fig. 2(a) to 2(f) are timing charts for explaining an operation of an EL driving device according to the present embodiment.

Fig. 3 is a driving circuit diagram in case of applying the present embodiment to a matrix type EL display device.

Fig. 4 is a plain explanatory view of an EL driving device of the present embodiment.

Fig. 5 is a cross-sectional explanatory view of A-A line of Fig. 4.

Fig. 6 is a simple equivalent circuit diagram of the conventional EL driving device.

Fig. 7 is a graph showing the relation of a driving voltage and the luminance in an EL driving device.

Fig. 8 is a graph showing the relation of the driving frequency and the

luminance in an EL driving device.

Fig. 9 is a graph showing the relation of a gate voltage of a switching element for driving and the luminance in an EL driving device.

Fig. 10(a) and 10(b) are timing charts for explaining a light emitting operation of an EL light emitting element.

Fig. 11 is a simple equivalent circuit diagram of an EL driving device that the present inventor proposed in the past.

[Description of the Reference Numerals and Signs]

10...transparent substrate

11...transparent electrode

12...first dielectric layer

13...light emitting layer

14...second dielectric layer

15...back electrode

31...cathode electrode

22...semiconductor layer

33...anode electrode

Qw...first switching element

Qd...second switching element

CEL...EL light emitting element

Cs...condenser for storage

PD...photodiode

Va…EL driving power source